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(54) Title: FLEXIBLE SMOKE GENERATOR

(57) Abstract: A flexible smoke generator comprising smoke composition particles embedded in an elastomer, preferably a silicone rubber compound that is molded or extruded into a relatively thin layer. The smoke generator may further comprise flexible circuitry to provide a currency alarm pack having the flexibility and feel of a standard currency pack without an alarm. The smoke composition particles may contain a red dye and/or tear gas. The smoke composition particles have a preferred particle size range small enough to pass through a number (18) sieve and large enough not to pass through a number (40) sieve. The smoke generator may be provided with a film covering, such as polyurethane, which may provide sealing capability for sealing the smoke composition particles and/or tear gas within the elastomer. The smoke generator may contain embedded reinforcing fibers for additional strength.

FLEXIBLE SMOKE GENERATOR

CROSS-REFERENCE TO RELATED APPLICATIONS

This application claims priority based upon U.S. Application Serial Number 09/605,071, filed on June 28, 2001, incorporated herein by reference.

FIELD OF THE INVENTION

The present invention relates to the field of smoke generators. More particularly, the present invention relates to a pyrotechnic smoke generator which is flexible.

BACKGROUND OF THE INVENTION

In one field of application of the present invention, although the present invention may be applied in other fields, there has been a need for a smoke generator that may be inserted into a pack of currency bills without it being readily obvious that the pack of bills contains the smoke generator. One major application of this technology today is in the field of foiling bank robberies and robberies of other financial institutions and money transporters. In the past, the center of a currency pack has been cut out and a security dye pack including a smoke generator either in the form of a plurality of rigid pellets or a plastic bag containing smoke composition were mounted in the currency pack. For example, U.S. Patent No. 5,059,949 to Caparoni et al. and U.S. Patent Nos. 5,196,828 and 5,485,143 to Keniston describe existing currency alarm pack systems.

It is very desirable in the field of currency alarm packs to provide a pack having the smoke generator and corresponding circuitry that so resembles and feels like a normal, unalarmed currency pack that a thief cannot detect that it is an alarmed

currency pack. Thus, it is important that the smoke generator have lateral and torsional flexibility approaching that of a stack of currency of the same thickness.

SUMMARY OF THE INVENTION

The present invention comprises a smoke-generating apparatus comprising an elastomer layer, such as a silicone layer, having smoke composition particles dispersed throughout the elastomer or silicone layer and adapted to generate smoke when activated, wherein the elastomer or silicone layer containing the smoke composition particles is flexible.

The smoke composition particles may comprise a fuel, an oxidizer, and a compound having an opaque sublimation product at a temperature generated upon initiation of an oxidation reaction between the fuel and the oxidizer. In one embodiment, the smoke composition particles contained in the smoke generator may contain a red dye. In other applications, any suitable color of dye or no dye may be used. In an another embodiment, particularly when used for anti-theft purposes, the smoke generator may further comprise a tear gas composition. In one embodiment, the smoke composition particles may have a particle size small enough to pass through a number 18 sieve, but large enough not to pass through a number 40 sieve.

The smoke generator may further comprise a flexible circuit adjacent thereto, including an antenna for receiving an activation signal, a power source, such as one or more batteries, and an electrically-activated ignition source.

The smoke generator may further comprise a film on its outer surface to enhance the strength, flexibility and slidability of the smoke generator with respect to the currency, and also to provide an additional sealant for the red dye and tear gas components within the elastomer layer, when applicable. The elastomer layer may be provided with reinforcing fibers, such as for example fiberglass, carbon, or aramid

fibers (such as Kevlar® manufactured by E. I. duPont de Nemours and Company, of Wilmington, Delaware), to increase its strength.

BRIEF DESCRIPTION OF THE DRAWINGS

For the purpose of illustrating the invention, there are shown in the drawings forms which are presently preferred; it being understood, however, that this invention is not limited to the precise arrangements and instrumentalities shown.

Figure 1 is a perspective view illustration of a smoke generator of the present invention.

Figure 1A is a partial cutaway perspective view illustration of a portion of a smoke generator embodiment of the present invention having a covering film.

Figure 1B is a perspective view illustration of a portion of a smoke generator embodiment of the present invention having reinforcing fibers.

Figure 2 is a side elevation view illustration of a portion of a smoke generator of the present invention mounted adjacent to ignition control circuitry components shown in dotted outline form.

Figure 3 is a side elevation view illustration of a currency pack containing a smoke generator and ignition control circuitry embodiment of the present invention, wherein the smoke generator is shown in partial longitudinal section.

DETAILED DESCRIPTION OF THE INVENTION

Referring now to the drawings, where like numerals indicate like elements, there is shown in Figure 1 a smoke generator 10 which is comprised of an elastomer, preferably silicone, forming a layer with smoke composition particles dispersed

throughout. The elastomer may comprise any of the various types of elastomers capable of providing a desired degree of flexibility and elasticity, preferably sufficient flexibility and elasticity to provide full lateral and torsional flexibility. The elastomer is preferably stable at temperatures above those at which the smoke composition is activated, to avoid the absorption of heat from the smoke generating reaction, which may be a sublimation process. For example, silicone materials, particularly flexible silicon elastomer resins, such as two-part, room-temperature, vulcanizing silicone rubber compounds, may be used. Any type of silicone or elastomer, however, may be used.

One embodiment may use RTV 615 silicone, commercially available from General Electric Company, which has a useful temperature range from -60°C to 204°C. RTV 615 silicone is a two-part silicone -- one part is a resin and the other part is a catalyst. The mixture of the two parts produces an odorless-curing silicone that cures in the absence of moisture. Another acceptable silicone is Silastic® S, manufactured by the Dow Corning Corporation of Midland, Michigan. It should be understood that to the extent that the specification refers to specific embodiments using specific brands or grades of silicone rubber compounds, various other elastomers may be utilized in practicing the present invention, including in the various alternate embodiments. Preferred elastomers remain stable during the smoke generating reaction.

The smoke composition particles may be produced from various known active chemicals used for this purpose in the industry. The term "active chemicals" as used herein, encompasses any non-inert chemicals that may be utilized in applications of the type herein discussed, including those for generating smoke from a sublimation process, dyes of various colors, and/or tear gas generating compositions. An exemplary smoke composition may comprise by weight approximately 49.25% ± 5% red dye, 28.25% ± 5% potassium chlorate, 21.75% ± 5% sugar, such as confectioner's sugar, and 0.75% ± 0.75% inert binder, such as magnesium stearate. It should be noted that confectioner's

sugar by definition contains cornstarch, and thus the formulations used herein may contain cornstarch in addition to finely pulverized sugar. The binder is optional. For example, one embodiment may comprise approximately 51.5% red dye, 27.5% potassium chlorate, 21.0 % sugar, and 0.0% binder. A preferred red dye is Disperse Red 9, also known as 1-(methylamino)-9,10-anthracenedione (MAA) or 1-methylamino-9,10-anthraquinone. Other sufficiently volatile dyes that convert to a vapor state without decomposing are also suitable. Volatile dyes typically have a relatively low molecular weight.

In the mixtures identified above, the potassium chlorate is an oxidizer, the sugar is a fuel, and the red dye is a smoke-generating compound that sublimes to produce an opaque vapor when exposed to the heat generated by the oxidation reaction between the sugar and the potassium chlorate. The invention is not limited, however, to any particular composition, and may include any composition of a fuel, an oxidizer, and a smoke-generating compound. Although potassium chlorate is a desirable oxidizer because of its low decomposition temperature that is high enough to remain stable but low enough to prevent decomposition of the dye, other oxidizers with similar properties relative to the corresponding dye may also be used. Other fuels may also be used, including but not limited to sulfur, lactose, sucrose, and the like. The "smoke" may be a sublimation product or may comprise any combination of airborne particles, vapor, or gas that are visible enough to attract attention when the smoke generator is activated.

The ratio of fuel to oxidizer may be varied as necessary to reach a desired temperature required to activate the smoke-generating compound. A balance of fuel and oxidizer is desired, however, that avoids a fuel-rich mixture that may create an inefficient, sooty reaction or an oxidizer-rich mixture that may create a reaction having excess oxygen available to react with the dye. Optimal blends of the active chemicals produce enough heat when activated to vaporize the dye without chemically changing or decomposing it, and produce enough gas to disperse the dye vapor. Too much heat generation can create poor smoke or cause a flame-up of the smoke-generating device.

The blend of active chemicals may also be tailored to have heat generation properties that match the properties of the elastomer in which it the smoke composition particles are to be dispersed.

The smoke composition components may be dry blended or mixed and pressed into a form such as a pellet, which is then suitable for grinding or granulation. In one embodiment, the ground smoke composition particles that result from the grinding or granulation step have a particle size small enough to pass through a number 18 sieve, but large enough not to pass through a number 40 sieve. Particle sizes outside this range may also be used, provided the particles produce smoke via a solid state chemical reaction that is not impeded by the elastomer when initiated, such as a sublimation process. Typically, larger particles produce more heat than small particles, and thus the granulation size is a factor in maintaining propagation of the reaction from one smoke granule to the next through the elastomer. The aforementioned particle size range has been found to produce a desirable rate of smoke output on the order of about 5 to about 10 seconds of smoke per square inch of 0.1 inch thick smoke generator. The rate and duration of smoke output may be varied by varying the particle size and composition of the smoke generating particles, the ratio of smoke granules to elastomer, and/or the amount of caloric input used to initiate the oxidation reaction.

In manufacturing the smoke generator of the present invention, the two parts of the silicone rubber compound are mixed to produce a liquid having a viscosity in the range of, for example, about 4000 to about 12,800 centipoise. This allows manageable mixing of the smoke composition particles with the elastomer and subsequent molding or extrusion of the mixture. It is desirable to keep the viscosity high enough that the smoke particles do not settle to the bottom, yet low enough to facilitate easy processing. For example, preparing an embodiment by manual mixing smoke composition particles into the RTV 615 elastomer liquid, produces a viscosity of about 4,000 centipoise, whereas an embodiment prepared with Silastic® S produces a viscosity of about 12,800. It is understood, however, that the viscosity of the elastomer liquid prior to curing may

vary outside of this exemplary range. In particular, with mechanized mixing and where extrusion is performed, the viscosity values may be significantly greater than the above viscosity. Even with manual mixing, the viscosity may vary significantly.

The smoke composition particles, in particular particles having a size between a number 18 and a number 40 sieve as described above, may be mixed with the silicone or other elastomer in a ratio of about 2.4 to about 4.0 grams of smoke composition particles per gram of silicone. The elastomer containing the particles may then be molded or extruded to any desirable shape, and then allowed to cure. For use in connection with currency security packs, the elastomer containing the smoke composition particles is preferably molded or extruded into a thin layer of about 0.25 inches thick or less, preferably about 0.125 inches thick. When used in connection with currency security dye packs, the width and height of the molded or extruded silicone is equal to or less than the length and width of the currency in connection with which it is intended to be used. In one embodiment for use with United States paper currency which is approximately 6 3/16 inches long and 2 5/8 inches wide, for example, the length of the smoke generator may be about 3.9 inches and the width about 1.9 inches. Positioning tabs, similar to those shown and described in U.S. Patent 5,059,949 to Caparoni et al. and incorporated herein by reference, may be used on the associated ignition control circuitry.

Referring now to Figure 1A, there is shown an alternate embodiment of the present invention wherein a smoke generator 12 is constructed as having a core section 14 similar to that as described with respect to Figure 1, with a film or coating 16 covering the outer surface. Film, coating, or covering 16 may comprise polyurethane, such as that commercially available from the 3M Company under the trademark TEGADERM®, or other suitable material capable of providing additional strength for smoke generator 12 as well as additional sealing capabilities. The additional strength enables flexing to a greater degree without risk of the elastomer or silicone layer breaking. TEGADERM® film provides strength and memory, enhancing the ability of

the elastomer layer to return to its original shape. Film or coating 16 may further have a high lubricity or low friction, particularly when used as a smoke generator in a currency security pack, so that the smoke generator can slide easily against the adjacent currency bills when the currency pack is flexed.

Also shown in Figure 1A is a space 18 in the core of smoke generator 14, such as for receiving a pellet or pill. In one embodiment, a pill or pellet comprising tear gas may be placed in cavity or space 18. Alternatively, the tear gas composition may be mixed in with the elastomer or silicone as a part of the smoke composition material. In the embodiment shown in Figure 1A, film or coating 16 may provide additional sealing to prevent any leakage of tear gas from the material.

Referring to Figure 1B, there is shown an alternate embodiment wherein smoke generator 20 comprises an elastomer 22 with smoke composition particles 24 distributed therein along with reinforcing fibers 26. The reinforcing fibers may be any suitable type of reinforcing fibers such as glass fibers, such as those commercially available under the FIBERGLAS® trademark of Owens-Corning Corporation, or carbon fibers.

Referring now to Figure 2, there is shown a smoke generator 30 in side elevation and partial cutaway to show particles 32 therein. Flexible ignition control circuitry 34 is shown in dotted outline form. The flexible ignition control circuitry may be circuitry formed on a flexible substrate, such as MYLAR® polyester film manufactured by DuPont, with appropriate components thereon. One of these components may be an electrically activated ignition source, such as, for example, a device referred to as an "electric match." Any ignition source having sufficient heat output to activate the smoke generator may be used, however. The ignition source is connected to or in contact with smoke generator 30 to initiate the smoke-generating process of particles 32 in response to an electrical signal. The electrically activated ignition source may be held in contact with the smoke generator using a high temperature tape. Other components on the flexible ignition control circuitry may

include an antenna (not shown) for receiving an activating signal, as well as a magnetic reed switch (not shown), and a power source (not shown), such as one or more batteries, as are commonly used in these applications. The background section of U.S. Patent No. 5,485,143 describes the manner in which a magnetic reed switch or an antenna may be used in this application. "Ignition" as referred to herein refers to initiation or activation of the reaction that causes smoke to be generated, such as initiation of the potassium chlorate and fuel oxidation reaction that causes the red dye to sublimate.

Referring now to Figure 3, there is shown a smoke generator 30 and associated flexible ignition control components 34 positioned in a currency pack 36 which has been flexed in a "S" shape. The flexibility of smoke generator 30 allows flexing of currency pack 36, allowing the currency pack to present a feel similar to that of a currency pack without a security alarm pack contained therein.

The smoke generator of the present invention described above may have a number of desirable qualities. It is typically very flexible, having both lateral flexibility and torsional flexibility. As used herein, the term "flexible" refers to its common meaning: "able to bend without breaking; not stiff or rigid; easily bent; pliant." *Websters New World College Dictionary*, Third Edition, 1997. In particular, the desired flexibility is flexibility comparable to a corresponding thickness of paper currency in which the smoke generate is to be inserted, so that the smoke generator mimics the feel and bending characteristics of the paper currency such that its presence is not readily detected by a thief. The elastomer or silicone provides a certain degree of elasticity that enhances its flexibility. The smoke generator of this invention may be formed into any shape, particularly into a thin layer, which is advantageous for use in a security currency pack. The thinness may allow its use in a money pack without cutting out the center of the money pack. Because the smoke composition, including any dye therein, is embedded in the elastomer, the dye and other active chemicals are not exposed to the users, thus minimizing the possibility of getting red dye or other active

chemicals dispersed about the work area. The smoke generator of this invention may be manufactured separately from the ignition source and may also be shipped separately from the electric ignition source, making shipment safer and subject to less regulation.

The present invention may be embodied in other specific forms without departing from the spirit or essential attributes thereof and, accordingly, reference should be made to the appended claims, rather than to the foregoing specification as indicating the scope of the invention.

CLAIMS

I claim:

1. Smoke-generating apparatus, comprising:

an elastomer formed in a layer; and

a plurality of smoke composition particles dispersed throughout said elastomer and adapted to generate smoke when activated;

wherein the smoke-generating apparatus is flexible.

2. The smoke-generating apparatus of claim 1 wherein the elastomer comprises silicone.

3. The smoke-generating apparatus of claim 1 wherein the smoke composition particles have a particle size small enough to pass through a number 18 sieve, but large enough not to pass through a number 40 sieve.

4. The smoke-generating apparatus of claim 1 wherein the ratio by weight of smoke composition particles to elastomer is in a range of about 2.4 to about 4.0 grams of smoke composition particles per gram of elastomer.

5. The smoke-generating apparatus of claim 2 wherein said silicone comprises a two-part, room-temperature vulcanized silicone rubber compound.

6. The smoke-generating apparatus of claim 5 wherein the two-part silicone rubber composision comprises a resin part and a catalyst part that are mixed to produce a silicone that cures in the absence of moisture.

7. The smoke-generating apparatus of claim 1 wherein the elastomer comprises an elastomer that prior to curing has a viscosity that enables mixing of the smoke composition particles into the elastomer to form a mixture in which the smoke composition particles do not settle out and further enables molding or extrusion of the mixture.

8. The smoke-generating apparatus of claim 7 wherein said elastomer layer prior to curing comprises silicone and has a viscosity of about 4,000 to about 12,800 centipoise.

9. The smoke-generating apparatus of claim 1 further comprising a coating that encases the elastomer layer.

10. The smoke-generating apparatus of claim 9 wherein the coating comprises polyurethane.

11. The smoke-generating apparatus of claim 1 wherein the smoke composition particles comprise a dye.

12. The smoke-generating apparatus of claim 11 wherein said dye is a red dye.

13. The smoke-generating apparatus of claim 1 wherein the smoke composition particles comprise an oxidizer, a fuel, and a compound having an opaque sublimation product at a temperature generated upon initiation of an oxidation reaction between the fuel and the oxidizer.

14. The smoke-generating apparatus of claim 13 wherein the smoke composition particles comprise by weight approximately:

49.25% ± 5% red dye;

28.25% ± 5% potassium chlorate;

21.75% ± 5% sugar; and optionally

0.75% ± 0.75% inert binder.

15. The smoke-generating apparatus of claim 14 wherein the inert binder is magnesium stearate.

16. The smoke-generating apparatus of claim 14 wherein the sugar is confectioner's sugar.

17. The smoke-generating apparatus of claim 14 wherein the smoke composition particles comprise by weight approximately:

51.5% red dye;

27.5% potassium chlorate,

21.0% sugar.

18. The smoke-generating apparatus of claim 13 wherein the smoke composition particles comprise particles that have been dry blended, pressed into a shape, and then granulated to a smaller particle size.

19. The smoke-generating apparatus of claim 1 further comprising:

an electrically-activated ignition source in contact with said elastomer layer; and

a flexible electrical circuit adapted adjacent said elastomer layer for activating said electrically-activated ignition source.

20. The smoke-generating apparatus of claim 19 wherein said flexible electrical circuit includes an antenna.

21. The smoke-generating apparatus of claim 1 wherein said smoke composition particles comprise a tear gas composition.

22. The smoke-generating apparatus of claim 1 wherein the elastomer layer comprises a space for receiving a tear gas pellet and means for sealing said tear gas pellet in said space.

23. The smoke-generating apparatus of claim 1 wherein said elastomer comprises embedded fibers.

24. The smoke-generating apparatus of claim 23 wherein said fibers comprise glass fibers, carbon fibers, aramid fibers, or a combination thereof.

25. The smoke-generating apparatus of claim 12 wherein the dye comprises 1-(methylamino)-9,10-anthracenedione.

26. A currency pack comprising at least one smoke-generating apparatus of claim 1.

FIG.1

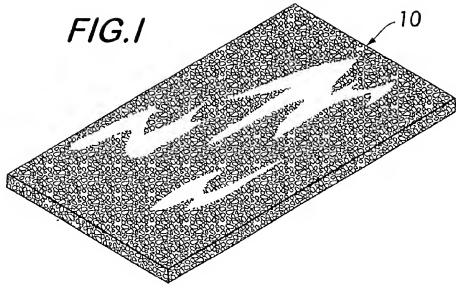
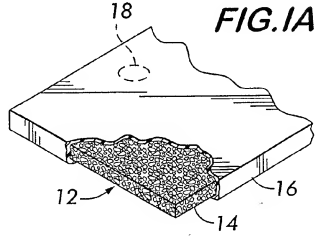


FIG.1A



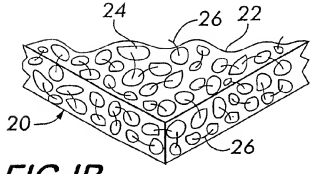
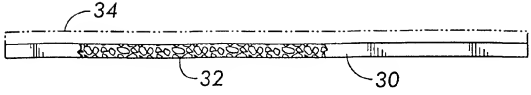


FIG.1B

FIG.2



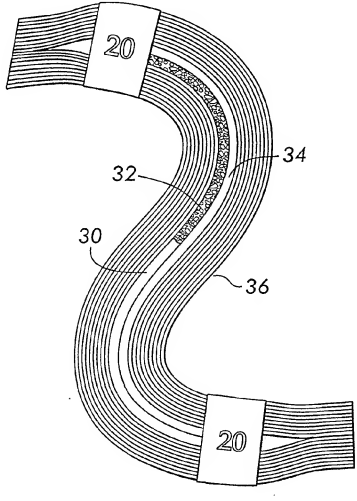


FIG.3